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THE PATENT OFFICE LONDON

(54) METHOD AND MEANS FOR TRANSMITTING MEASURING DATA

(71) We, SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B. V., a company organized under the laws of the Netherlands, of 30, Carel van Bylandtlaan, The Hague, the Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:–

The invention relates to a method and means for transmitting measuring data. In particular, the invention relates to transmission techniques wherein data have to be transmitted under conditions where electric signal cables cannot be used and wave signals (such as radio or acoustic waves) are heavily attenuated or distorted. Such conditions exist amongst others in wells that are being drilled in subsurface formations. During such well drilling operations, the drilling crew needs information on the conditions at or near the bottom of the hole. Such information may be required on the inclination of the hole, on the bottom temperature, and/or on the bit wear, etc. Several techniques for data transmission have been suggested and tried in the past.

One of these techniques makes use of means carrying the data to be transmitted in a suitable form (such as by imprint on the surface of the body, or magnetization of the body in a particular code), which carrier means are displaced from the bottom of the hole being drilled to the surface by the flow of drilling mud returning to the surface. The carrier means are separated from the mud at a surface location and subsequently read out to recover the measuring data therefrom.

Transport of the carrier means over the depth at which the borehole extends takes some time, but once the carrier means have arrived at the surface, the data carried thereby are available in an undistorted form.

An object of the invention is to provide a method for data transmission of the above type, which method is inexpensive and reliable.

Another object of the invention is to provide a means for data transmission of the above type, which means are inexpensive and easy to handle.

According to the invention, a method of transmitting measuring data comprises a sequence of steps, each step including the supply of measuring data to an assembly of interconnected semi-conductor memories followed by detaching one such memory from the rest of the memories and transporting the detached memory to a region where the measuring data are required.

According to the invention, a means for transmitting measuring data comprises an assembly of semi-conductor memories, an electric circuit system for supplying measuring data to at least one of the memories, and means for removing the said memory from the other memories of the assembly.

The memories may be interconnected in the form of a strip, and the means for removing the said memory from the other memories of the assembly may be formed by detaching means.

The memories are constituted by shift registers, random excess memories, programmable read only memories or any other semi-conductor devices that are suitable for sotring information in digitized form.

The invention will be described by way of example in more detail with reference to the drawings, in which:

Figure 1 shows schematically a longitudinal section of a strip of data transmission elements (each comprising a semi-conductor memory) of which one element has been removed;

Figure 2 shows schematically a section of the strip of data elements of Figure 1, and taken in the direction of arrows II-II;

Figure 3 shows schematically a top view of an arrangement of data transmission elements other than the arrangement shown in Figure 1;

Figure 4 shows a section taken in the direction of arrows IV-IV in Figure 3;

Figure 5 shows a drill string carrying means according to the invention;

Figure 6 shows an enlarged section taken in the direction of arrows VI-VI in Figure 5;

Figures 7 and 8 show sections taken in the direction of arrows VII-VII and VIII/VIII, respectively, in Figure 6; and

Figure 9 shows an example of an electric circuit including a semi-conductor memory and an electric circuit system for supplying measuring data to the memory and for supplying signals to actuating means for detaching the memory from the rest of the memories.

Figure 1 of the drawings shows schematically one end of a strip of data transmission elements 1 according to the invention, of which the most right-hand element 2 has already been removed in a manner that will be explained hereinafter.

Each data transmission element 1 comprises a semi-conductor memory 3 electically connected to the electic circuit system 4 by a plurality of leads 5. The memories 3 are mechanically interconnected by the electric circuit system 4 as well as by the body 6 of protective material that is provided with a weakened portion 7 between adjacent elements 1. In each weakened portion 7, a charge 8 of explosive material is positioned, which charge is provided with electric igniting means (not shown) that are connected by leads 9 to the electric circuit system 4. Such charges of explosive material of small dimensions as well as igniting means for igniting said charges are known per se and do not need any further description.

Each element 1 further comprises an electric accumulator 10 that is electrically connected by leads 11 to the semi-conductor memory 3 of the relevant element. This accumulator is used for supplying the required energy to the memory 3 of the data transmission element after the element has been detached from the strip of elements.

Further, read-out contacts 12 are arranged in the surface of the body 6, these contacts being connected to the memory 3 by leads 13.

It will be appreciated that the electric circuit system 4 as well as the leads 5, 9, 11 and 13 may include a plurality of auxiliary components that may be required for the operation of the main components 3, 8, 10 and 12 of each data transmission element. For sake of simplicity, these auxiliary components have not been shown in Figures 1 and 2, but a description thereof will be given later on with reference to Figure 9.

The body 6 consists of a material that protects the components (including the electric cables and leads) inside the body against damage, such as mechanical and chemical damage. Further, the body 6 insulates the components enclosed therein when the element is in an electrically conductive liquid environment such as is present in a borehole that is being drilled and has drilling mud circulating therethrough.

One end of the electric circuit system 4 extends outside the strip of elements 1 and has an electric coupling 14 attached thereto. When installed in a drill string that is to be applied in a borehole, the coupling 14 is coupled to a measuring element carried by the drill string, said measuring element including a timer adapted to operate the electric igniting means of each detaching means 8 consecutively at predetermined moments to detach from the rest of the data transmission elements each time a fresh element that is carrying the latest measuring data in the memory thereof.

It will be appreciated that any measuring element and any timer suitable for being used in a borehole under the pressure and temperature conditions prevailing therein may be used for this purpose. Since such measuring elements (for measuring pressure, temperature, inclination, etc.) and timers are known per se, they do not need any further detailed description. The same applies for the electric accumulator that is used for supplying electric energy to the assembly of data transmission elements, to the timer and to the measuring equipment.

An alternative arrangement of the data transmission elements is shown in Figures 3 and 4 of the drawings.

In the arrangement shown in Figures 3 and 4, the weakened portions 20 having detaching means 21 (such as small explosive charges) situated therein are arranged alongside the electric circuit system 22. The body 23 of protective material envelopes the detaching means 21 and the circuit system 22, as well as the semi-conductor memories 24, the electric accumulators 25 and the various leads (not shown) interconnecting these components. Local interruptions 26 are arranged in the body 23 to separate adjacent semi-conductor memories 24, thereby forming data transmission elements 27 that are at one side thereof attached to the continuous part of the body 23 of protective material, which continuous part envelopes the electric circuit system 22.

A plurality of read-out contacts 28 is arranged in the surface of the body 23 of each data transmission element 27. The contacts are in electric communication with the semi-conductor memory 24 of the relevant element 27.

As shown in the drawing, the data trans-

mission element 27' has just been shot off by igniting the detaching charge 21' thereof. Further, the sheared portion 20' of the body 23 of protective material indicates the place where the most right hand data transmission element (not shown) of the strip of data transmission elements was attached to the continuous part of the body 23.

It will be appreciated that all components of the data transmission elements (such as electric circuit system, the semi-conductor memories, the electric accumulators, the read-out contacts, the detaching means and all other auxiliary components that are not shown in Figures 1-4 of the drawings) may be mounted on a common strip-like element, such as a printed circuit plate of a length sufficient to support the assembly of semi-conductor elements. The printed circuit plate will show interruptions similar to interruption 26 when the arrangement of Figure 3 is used. In an alternative embodiment, only part of the components may be supported by said strip-like element. By using a printed circuit plate, the components (or part thereof) may be formed directly on one or both of the sides of the plate.

Reference is now made to Figures 5-8 of the drawings to illustrate the manner in which the means for transmitting measuring data according to the invention may be installed in a drill string adapted to operate in boreholes that should penetrate in underground formations.

Figure 5 shows the lower part of such drill string, which lower part comprises a drill collar string consisting of a plurality of drill collars 30 that are interconnected in end-to-end relationship. A drill bit 31 (such as a diamond bit) is connected to the lower end of the drill collar string. One of the drill collars 30 comprises a groove 32 (see also Figures 6-8) in the outer surface of its wall, which groove houses an assembly 33 of interconnected semi-conductor memories according to the invention. In the example shown, the assembly 33 is in the form of a strip of data transmission elements as shown in Figures 1 and 2.

The groove 32 further houses a liquid-tight case 34 carrying measuring equipment for obtaining information on a phenomenon in the borehole (such as the inclination thereof), an electric accumulator for supplying electric energy to the components in the case 34 as well as to the data transmission elements, signal conditioning equipment (such as an electronical filter and/or an amplifier) and an analog digital converter. Equipment of this type is known per se and does not need any detailed description. Measurement data in digitzed form are passed on to the semi-conductor memories in the assembly 33 of these memories via the liquid-tight electric coupling 35.

The case 34 further encloses a timer, which is set to give a plurality of activating signals after a predetermined time interval (required to bring the drill string down in the hole to a position wherein the bit 31 can drill the bottom of the hole), which signals periodically activate the measuring means and a single detaching means (means 8 in Figures 1 and 2, and means 21 in Figures 3 and 4) to detach the data transmission element that is situated at the end of the strip, after the measured data have been supplied thereto. As shown in Figure 6, one such element 36 has just been detached and since the density thereof is smaller than the density of the drilling mud circulating through the hole being drilled, the element 36 will float upwards in the direction indicated by arrow 37. The upper end of the groove 32 is formed to faciliate such upward displacement of the elements that have been detached from the strip 33.

It will be appreciated that a clock may be applied on the surface which clock is synchronized with the timer in the case 34. The exact moments at which subsurface measurements are taken can then be discerned at the surface, and the drilling operation may be interrupted for the period over which the measurements take place, if the drilling operation would interfere with the measuring operation.

To protect the equipment housed in the groove 32, a cover plate 38 is arranged in the manner shown in the drawings, and connected to the drill collar 30 by means of screws 39. If desired, openings or holes (not shown) may be arranged in the cover plate to allow circulation of drilling mud through the groove 32.

The drilling mud that is being circulated through the borehole is supplied to the bit 31 through the interior of the drill string (incorporating the drill collar string) and flows to the exterior of the string through openings (not shown) provided in the body of the bit 31. Thereafter, the mud returns via the annulus around the drill string to the top of the borehole, thereby carrying upwards any cuttings that originate from the action of the bit. This upward flow of mud at the same time increases the velocity of the memory element 36 that is travelling to the top of the borehole. Once arrived at the top of the borehole, the mud is reconditioned for re-use. Prior to reconditioning the mud, any data transmission element carried thereby is removed therefrom, such as by means of a sieve. If desired, the elements may have certain properties that make them readily traceable in themud. After retrieval of a data transmission element, the data carried therein are read-out via the read-out contacts thereof by means of a suitable read-out equipment which may include display means.

It will be appreciated that the density of the memory element need not be necessarily lower than the density of the mud since the upward flow of mud is also able to transport bodies having a density higher than the mud density.

Reference is now made to Figure 9 of the drawings to exxplain by way of example the co-operation between the various components included in a data transmission element, and the way in which the elements can be selectively detached from the rest of the elements. The system shown in Figure 9 may be used in any one of the strips of data transmission elements shown in Figures 1, 2 and Figures 3, 4.

The semi-conductor memory 40 applied in the system shown in Figure 9 is of a usual type static shift register with single power supply, single phase clocking requirements and internal recirculating capability, and does not need any further description. The semi-conductor memory RCA CD 4031 AE is an example of such memory. The invention is not restrictted to the application of a particular type of semi-conductor memory.

The memory applied in the system shown comprises the following in/outputs:

A = positive power supply
B = data in
C = clock signal
D = mode control (logical 1 provides recirculation of data)
E = data out
F = recirculation in
G = earth.

In Figure 9, only part of an assembly of data transmission elements is shown. The element 41 described hereinafter extends between the sectins G-G and H-H (indicated by broken lines) and is positioned between identical elements 41' and 41''. Each element comprises a semi-conductor memory 40 as well as a number of other components that will be described hereinafter.

Electric energy and electric signals are passed to the data transmission elements through the electric cables 42-46 that correspond with the electric circuit system shown in Figures 1 and 2 and with the electric circuit system 22 shown in Figures 3 and 4 of the drawings. The signals are supplied to all the data transmission elements 41, 41', etc. and include measuring data and activating signals to ignite explosive detaching means.

Cable 42 is adapted for transmitting a firing signal to detaching means positioned between the data transmission element situated at the end of the strip and the rest of the elements.

Cable 43 supplies a clock signal at predetermined moments to each semi-conductor memory 40 to read in the measuring data passed on thereto via the cable 44.

Cables 45 and 46 are power supply cables. Cable 45 supplies the positive feed voltage to the various components of the data trasmission elements. This voltage should be somewhat higher than the voltage of the electric accumulator 47 in each element 41 to obviate energy drainage from this accumulator when the data transmission element is connected to the assembly of data transmission elements.

The accumulator 47 is arranged to supply electric energy to the semi-conductor memory 40 when the memory 40 has been detached from the electric cables 42-46. A diode 48 has been arranged to separate the accumulator from the voltage supply cable 45. The accumulator voltage is slightly lower than the supply voltage.

A plurality of transistors 49, 49', etc., is arranged between the firing signal cable 42 and the common cable 46. Electric detonating means 50 are incorporated in the emitter circuits of the transistors 49, 49'', etc. in the manner shown in relation to the transistor 49. Further, the base of each transistor is connected directly to the common cable 46 (see leads 51, 51' etc.), and through the intermediary of a resistor (see resistors 52, 52' etc.) to the supply voltage cable 45.

It will be appreciated that the detachment of the data transmission element 41'' at the left side of the element 41 will break off all electric connections that pass through the section G-G. By subsequently applying a positive voltage signal to the cable 42, the transistor 49 is the only transistor that will conduct and the detonating means 50 in the emitter circuit thereof will be activated to ignite an explosive charge situated along or near the line H-H. Thereby the data transmission element 41 containing the semi-conductor memory 40 will be detached from the rest of the assembly of data transmission elements. Since the explosive charge is arranged near the section H-H, the explosion of the charge will rupture the electric connection between the transistor 49' and the electric circuit at the left side of this section H-H. This transistor 49' will thereby become the next transistor to operate a detonating means when the next firing signal is supplied to the firing cable 42. If desired, suitable blocking means may be provided to prevent the activation of a successive number of transistors, these blocking means allowing activation of a detonating means only after the firing signal has died out. Such activation of a succesive number of transistors may also be prevented by time delay means in the detonator.

It will be appreciated that prior to detaching the data transmission element from the assembly of similar elements, the measuring data have been supplied to the semi-conductor memory 40 thereof. These data will be in digitized form and originate

from a measuring means. An analog-digital converter (not shown) is inserted between the measuring means (not shown) and the entry to cable 44, and the measuring data in ditigized form are supplied to the assembly of data transmission elements via this cable 44. The data input in the semi-conductor memories 40 is controlled by clock signals supplied via the cable 43 to the input C of each memory 40.

The diodes 53, 54 and 55 are incorporated in suitable parts of the electric system shown in Figure 9 to prevent the memory 40 from being drained of the information stored therein, when the data transmission element 41 has been detached from the rest of the elements and the ends of the cables 42-46 (which cables then no longer form an active part of the electric system of the assembly of data transmission elements) are exposed to the drilling mud which is a liquid with electrically conductive properties.

The electric cables 42-46 form part of a low-impedance system and the voltage levels on the active parts of the various cables 42-45 will therefore not be influenced by the ends thereof being in contact with an electrically conductive liquid.

The capacitor 56 has been arranged across the electic accumulator 47 to smooth transient voltage variations when the supply of electric energy through cables 45, 46 is taken over by the electric accumulator 47. This occurs when the electric circuit system incorporating cables 45, 46 is broken across section H-H.

It will be appreciated that – if required – more than one accumulator 47 may be present in each element 41 (such as when the semi-conductor memory 40 is of a design that requires supply voltages of different values). In case the memory 40 does not need electric energy for storing the measuring data during the transport thereof, the electric accumulator 47 is of course omitted.

In the system shown in Figure 9, the measurement data that are periodically supplied to the semi-conductor memories are supplied to all the memories simultaneously. After one of the memories has been detached from the assembly of memories, the information stored in the rest of the assembly is subsequently displaced therefrom by a fresh supply of measurement data, whereafter one of the memories comprising these fresh data is detached from the rest. This cycle may be repeated as many times as there are memories in the assembly.

Loss of a data transmission element during its transport from the bottom of the hole to the surface cannot be fully excluded under operational conditions. To prevent loss of measurement data, the system may be designed such that the fresh data do not remove all the old data from the memory, but only a part thereof. Preferably, the supply of fresh data removes all the old data save those of the period directly preceding the period over (or in) which the fresh data have been measured. However, the invention is not restricted thereto, but also includes the removal of all data save those data gathered in two or more preceding periods. In another embodiment of the invention, the data transported by each data transmission element may include – apart from the "fresh" measurement data – selected data from previous measuring periods.

In an alternative embodiment of the invention, the measurement data may be supplied to the data transmission elements just prior to detaching an element from the rest of the elements of the assembly thereof. In still another alternative embodiment of the invention, the measurement data may be supplied to the said memory elements over the whole period between successive detachment operations.

In again another embodiment of the invention, the data that are measured in a particular period are only supplied to and stored in the semi-conductor memory of the particular data transmission element that is first to be detached from the assembly of elements. Such selective supply of data to a single element may be obtained by an electric circuit that operates according to a principle similar to the one applied for selectively actuating the transistors 49, 49', etc. that control the detaching means.

Each step of the sequence of steps in the method according to the invention includes the supply of measuring data to a semi-conductor memory followed by transport of said memory to a region where this information is required. It will be appreciated that consecutive steps in this absence of steps may either overlap one another, or be separated by time intervals (which may range from a few minutes to several hours).

In the examples shown, each data transmission element comprises a single semi-conductor memory. However, the invention also covers the application of more than one semi-conductor memory per data transmission element, or the use of a plurality sub-memories. These memories may be used for separately storing measurement data of consecutive measuring periods.

The memories once they have arrived at the surface of a borehole are preferably read out directly to obtain the required information that is needed for taking decisions in the drilling operation. Reading out of a data transmission element as shown in Figure 9 may be done by electrically connecting the contacts 57, 58, 59 to a suitable read-out circuit and display means. The data stored in a semi-conductor memory 40 can be recircu-

lated during the reading-out step to prevent loss of said data. It will be appreciated that the resistor 60 is provided to prevent unwanted electric pulses from activating the input C of the semi-conductor memory 40, thereby acting as a false clock signal.

To distinguish the data transmission elements from each other on their arrival at the top of the borehole, they may be numbered either by painting figures or letters on the protective envelope thereof, or by incorporating a distinguishing feature in the measurement data stored therein. Any loss of an element in the train of elements that arrives at the top of the borehole can then readily be noticed.

It will be appreciated that apart from the detaching means described with reference to the drawings, other types of detaching means may be used for detaching the data transmission element that is situated at the end of a row of elements. Such other detaching means may be constituted by a miniature guillotine that is actuated by an electric motor or an electric magnet. Other types of detaching means may operate by applying heat or chemicals to the weakened portions of the assembly of data transmission elements to detach the desired element from the assembly.

WHAT WE CLAIM IS:–

1. A method of transmitting measuring data, said method comprising a sequence of steps, each step including the supply of measuring data to an assembly of interconnected semi-conductor memories followed by detaching one such memory from the rest of the memories and transporting of the detached memory to region where the measuring data are required.

2. A method according to claim 1, wherein the measuring data are read out of the memory at the region where the measuring data are required.

3. A method according to claim 1 or 2 wherein the memory transporter during one step also contains measuring data that are identical to at least part of the data stored in the memory transported during the previous step.

4. A method according to claim 1 or 2, wherein the measuring data are supplied periodically to each one of the interconnected memories of the assembly, thereby at least partially removing measuring data contained therein and resulting from an earlier step or earlier steps.

5. A method according to any one of the claims 4, wherein consecutive steps are carried out in overlapping time periods.

6. A method according to any one of the claims 1-4, wherein the periods over which consecutive steps are carried out are separated by time intervals.

7. A method of transmitting measuring data in a well, substantially as described with reference to Figures 508 of the accompanying drawings.

8. Means for transmitting measuring data, said means comprising an assembly of semi-conductor memories, an electric circuit system for supplying measuring data to at least one of the memories, and means for removing the said memory from the other memories of the assembly.

9. Means according to claim 8, wherein the memories are interconnected in the form of a strip, and the means for removing the said memory from the other memories of the assembly is formed by detaching means.

10. Means according to claim 8 or 9, wherein the memories and the electric circuit system are embedded in a body of protective material.

11. Means according to claim 9, wherein detaching means comprises electrically ignitable explosive means.

12. Means according to claim 9, wherein the detaching means is arranged to detach the said memory from the rest of the memories of the assembly by chemical action or a melting procedure initiated by an electric signal, to break the connection by which the said memory is attached to the rest of the memories of the assembly.

13. Means according to claim 9 and 10, wherein the strip of memories extends parallel tb the electric circuit system and the detaching means is arranged in those parts of the body of protective material that are situated between the said memory and an adjacent memory and between the parts of the electric circuit system associated with the said memory.

14. Means according to claims 10 and 11, wherein the strip of memories extends parallel to the electric circuit system, the body of protective material is interrupted between adjacent memories, and the detaching means is situated in those parts of the body of protective material that are sitated between the electric circuit system and the said memory.

15. Means according to any one of the claims 13 or 14, wherein the body of protective material is weakened in the regions where the detaching means is situated.

16. Means according to any one of the claims 8-15, comprising an accumulator for supplying electric energy to the said semiconductor memory when detached when other memories of the system.

17. Means according to any one of the claims 10 and 13-15, comprising read-out contacts in the surface of the body of protective material and electrically connected to the said memory.

18. Means according to any one of the claims 8-17, wherein the said memory com-

prises at least two sub-memories adapated for separately containing measuring data originating from measurements taken over different time periods.

19. Means according to claim 11 or 12, wherein a plurality of adjacent memories is provided with a like plurality of electrically ignitable detaching means comprising a like plurality of electric circuits, each circuit including a detonator for a detaching means of a memory, a transistor, a common firing signal cable and a common current return cable, both cables forming part of the electric circuit, the base of each transistor being connected to a common voltage supply cable and the common current return cable of the electric circuit system, one of these connections passing through the detaching area of an adjacent memory.

20. Means for transmitting measuring data, substantially as described with reference to Figures 1-4, Figures 5-8, and Figure 9 of the accompanying drawings.

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1549307 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

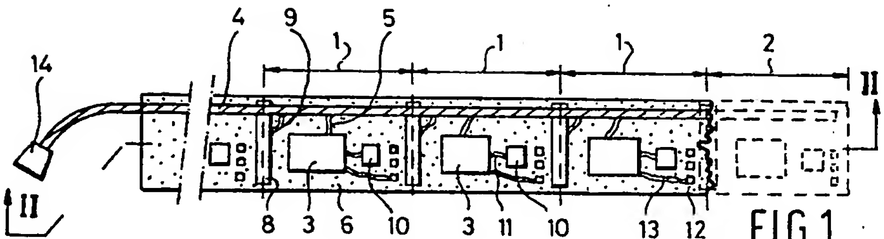

FIG.1

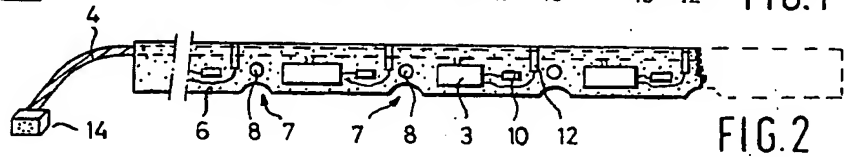

FIG.2

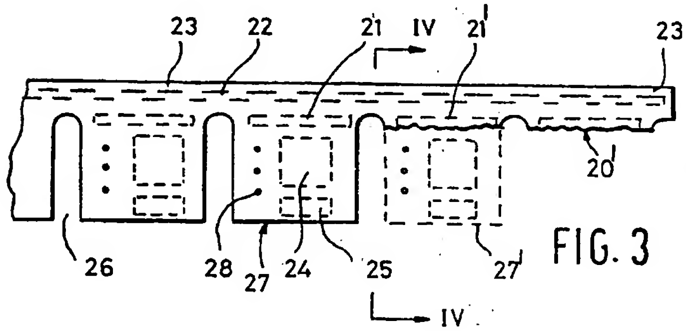

FIG. 3

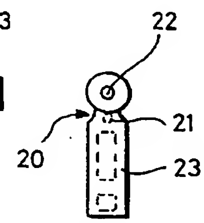

FIG.4

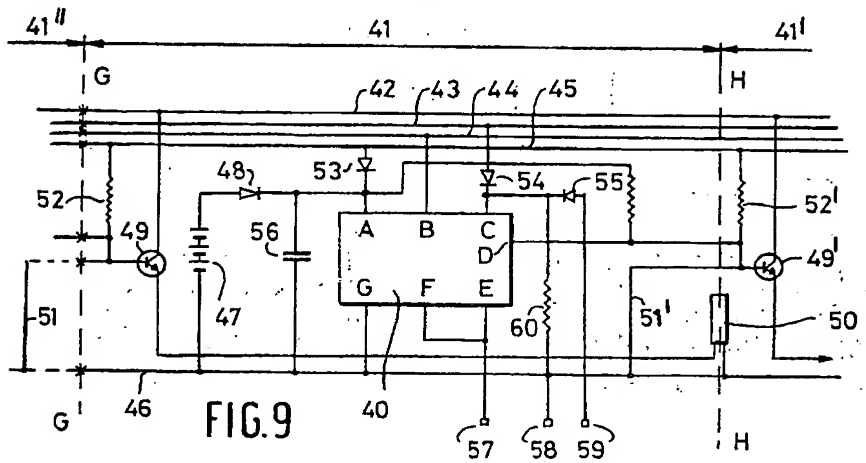

FIG.9

1549307 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

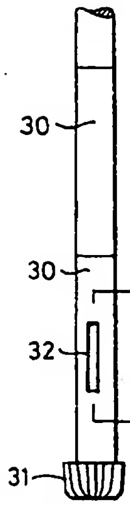

FIG. 5

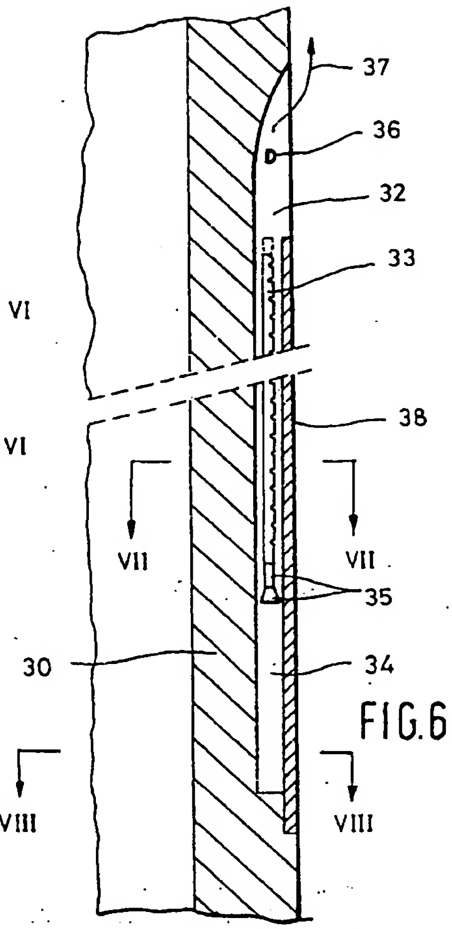

FIG. 6

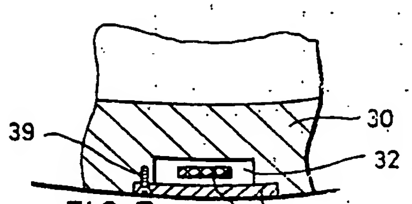

FIG. 7

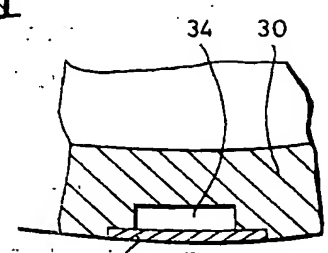

FIG. 8